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The water cycle at large scale over West Africa: an updated view from the AMMA project

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The large-scale water cycle of West Africa results from the interplay of various coupled ocean-atmosphere-land surface processes. The efficiency of these processes in controlling the advection of atmospheric humidity and its transformation into precipitation, and the destiny of rain water over land, are crucial aspects of the West African monsoon (WAM). Before AMMA, only few studies focused specifically on the water cycle of the WAM. These studies revealed satisfactorily basic elements of the seasonal cycle of precipitation and the main atmospheric circulation features that govern moisture transport. However, little was known about the mechanisms involved and the scales at which they operate. Also, the few studies that had evaluated water budgets at regional scale found very contrasting results, which led to contrasting interpretations on the functioning of the hydrological cycle at this scale. A major reason for this lack of consensus was the variety and composite nature of data sources used. Considerable effort was spent during AMMA at collecting new and pertinent observations at a broad range of spatial and temporal scales, running various state-of-the art atmospheric and land surface models, and analysing this huge amount of data in the framework of a coordinated FP6 European project.

This paper gives an overview of the large-scale continental water cycle studies conducted in AMMA. It covers mainly the intra-seasonal to inter-annual timescales of the atmospheric water budget using several different approaches.

First, a new hybrid dataset was developed which took great benefit from the AMMA Land surface Model Intercomparison Project (ALMIP). This approach provided an advanced, comprehensive atmospheric water budget dataset, including estimates of evapo-transpiration, rainfall, atmospheric moisture flux convergence (determined as a residual), together with surface fluxes, runoff, soil moisture tendency, and net radiation over the period 2002-2007. From this dataset, the hydrological cycle could be investigated with an unprecedented accuracy. It revealed that West Africa is a moisture source region during the dry season and a sink region during the wet season. Several limiting and controlling factors of the regional water cycle are highlighted, suggesting strong sensitivity to atmospheric dynamics and surface radiation. Some insight is also given into the underlying smaller-scale processes. The relationship between evapo-transpiration and precipitation is shown to be very different between the Sahel and the regions more to the South and partly controlled by net surface radiation. Strong correlations are found between precipitation and moisture flux convergence over the whole region from daily to interannual time-scales.

Second, several NWP model reanalyses have been used and inter-compared for water budget. Realizing that radiosondes in Africa had large humidity biases, a special reanalysis was also run at ECMWF in which a new radiosonde humidity bias correction method was applied and many additional offline data at high vertical resolution were assimilated. This reanalysis provided improved water budgets in comparison to previous NWP products. However, overall, significant deficiencies were revealed in the water cycle modelled by all NWP systems which are linked with problems in the models and with the lack of data assimilated over this region. The work in AMMA allowed diagnosing a number of problems in the models with greater confidence. Hypotheses are proposed about their origins and further improvements are foreseen.

The water cycle over the oceanic compartment of West Africa was also investigated. Usually, only satellite products are available over the ocean, but thanks to the PIRATA programme, many in-situ observations were collected during AMMA. These were used to evaluate sea surface temperature (SST) and heat fluxes from satellite products and atmospheric models. The link between SST and variability of the major weather systems over West Africa (mostly those that produce rainfall) was evaluated with different approaches. The intercomparison also allowed determining a diurnal bias correction for SST products which were used to force atmospheric simulations. SST forcing at high temporal resolution appeared important for accurate simulation of strong rainy events and propagation of African Easterly Waves over the Atlantic.